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UV Waterworks 2.0

Answers to Ten Commonly Asked Questions about the design, operation, and economics

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1. How much drinking water is provided per person per day?

The requirement of drinking water is estimated at 4 liters (1 gallon) per person per day for direct use. Including use for washing pots and pans, and use in cooking etc., Indian health ministry estimates 7 liters per person per day as more than adequate. Our design goal is 10 liters (2 and a half gallons) per person per day.

2. How clear must the inlet water be?

The UV transmittance of inlet water determines how well the UV light penetrates and disinfects the water column (for a broad review and many technical references, see Wolfe, 1990). Transmittance decreases with increasing turbidity and dissolved salts. The transmittance is measured with an "extinction coefficient." The larger the extinction coefficient, the faster the UV intensity gets extinguished as it travels through the water. Water with a large extinction coefficient for UV will protect microorganisms farthest away from the UV light source from being inactivated. The extinction coefficient of pure distilled water for UV is 0.007 cm^{-1}. The extinction coefficient of tap water is 0.1 cm^{-1}. In our design, we assume the inlet water to have the extinction coefficient of 0.3 cm^{-1}, as large as that of the average water discharged from US waste-water treatment plants. In laboratory experiments, we find that UV Waterworks can disinfect water with turbidities (produced by adding quantities of Kaolinite clay) of up to 20 NTUs.

3. What is the maintenance interval for UV Waterworks?

In the device, the UV lamp is the component with the shortest life: 8000 burning hours. When the lamp goes out (or there is any malfunction that interferes with the lamp operation), the users can see it immediately through a safe viewing window. Depending on the daily hours of use, the lamp can be replaced routinely once a year (e.g., for units used 20 hours a day), or once every 2 years (e.g., for units used 10 hours a day). We recommend routine cleaning and inspection every 6 months just to ensure smooth operation year round. Then the lamp could be replaced every other

maintenance visit, or every fourth visit. The only other part with a limited lifespan is the electronic ballast (typically rated at 20,000 burning hours). In some designs already on the market, the UV lamp is enclosed in a Teflon or quartz envelope and the whole assembly is immersed in the water being treated. However, these envelopes develop biofilms rapidly (in a few weeks) particularly if the water is stagnant intermittently (see the ref. below to van der Kooij et al., 1995). They can also develop deposits of salts from the inlet water. These biofilm and/or salt deposits significantly reduce the transmittance of UV light through the quartz or Teflon envelope, and thus reduce the disinfection ability of the device, unless the envelope is cleaned frequently (every few weeks). In the design of UV Waterworks, the UV lamp in positioned in air above the water column being disinfected. Thus, we have avoided having to enclose the UV lamp in either quartz or Teflon. This allows us to have large maintenance intervals, of the order of 6 months, with no adverse effects on system performance.

4. What is the quality of outlet water from UV Waterworks?

E-coli are commonly used as marker bacteria for biological contamination of water. E-coli concentrations in unsanitary drinking water at various developing world sites are typically found to exceed thousands per 100 mililiters (e.g., 30,000 per 100 ml reported at a site near Pune, India). The WHO standard specifies less than 1 per 100 ml for good drinking water quality, which is also the standard used in the industrial world drinking water supply. However, the high investments needed for meeting stringent quality standards for public water supply are just not available in most developing countries. Furthermore, many people in the developing world have a higher level of immunity to the pathogens in their water than the less exposed persons from industrial countries. A recent World Bank document (see ref. below) points out: "In most developing countries, the imperative is to get from "bad" quality (say, more than 1,000 fecal coliform per 100 milliliters) to "moderate" quality (less than 10 fecal coliforms per 100 milliliters), not necessarily to meet the stringent quality standards of industrial countries." Our design goal, however, is to reduce the e-coli concentration in the inlet water by 5 orders of magnitude (e.g., from 100,000 e-coli at the inlet to 1 e-coli at the outlet per 100 ml). UV Waterworks achieves this goal not just with clear water at the inlet, but also with turbid water (with a turbidities of up to 5 NTUs). We note here that the provision of disinfected drinking water for the community has to accompanied by: (1) the introduction (if necessary,) and use of narrow-mouthed vessels by the households for collection, transport and storage of water to reduce the possibility of recontamination, and (2) by appropriate community education in health and hygiene practices. On the use of narrow-mouthed vessels for preventing recontamination of sterilized drinking water in developing countries, see Mintz et al (1995).

5. Why did we choose the maximum inlet flow rate of 15 liters/minute?

The earlier units were designed and built and tested for disinfecting a maximum input flow rate of 30 liters (8 gallons) per minute. During the preliminary field tests of these units in India, we learned that this input flow rate is uncommonly high for water distribution systems in the real world. The most common application, where the device would be coupled to a handpump, would need a maximum input flow rate of 12 liters per minute (Alagarsamy et al, 1988) So, we redesigned the units to be cheaper and more compact with a maximum input flow of 15 liters per minute. The design is such

that if a larger flow is forced into the inlet, the excess water just overflows from the bottom slots in the device (i.e., it does not flood the insides of the device and cause electrical shorts).

6. Why does UV Waterworks use gravity flow in the design?

Other than for the production of the UV light, the UV Waterworks does not use any electricity. This has lowered the total power demand to just 40 watts. This allows the units to be hooked up to small size (2 sq. m.) photovoltaic panels, or to be used from car batteries that are exchanged for fresh batteries when they run down. In fact the installation at two of the Indian sites (villages Jatau and Bhupalpur in U.P., India) are operated in this manner. If more power were available, one could use it to operate a pump to lift the water or force it through a filter to remove giardia spores and other larger organisms.

7. How can one avoid giardia in the inlet water?

Giardia cause giardiasis -- a non-fatal diarrheal episode that can last for several days. Giardia spores are best removed by causing the particulates in the water to settle down using a flocculating agent (e.g., alum). These spores can also be removed with sand filters. Giardia spores are very rarely present in ground water. So, the simplest use of the UV Waterworks is to couple it with a handpump drawing ground water. If this is not feasible, then a sand-filter can be considered.

8. How energy efficient is UV Waterworks in disinfecting water?

UV Waterworks uses electricity. Commonly electricity is made by burning coal (or other fossil fuel) in a power plant with a conversion efficiency of about 33%. Thus we compare the amount of fossil fuel consumed to power the UV light, with the amount of fuel burnt in a cookstove to boil the water for disinfecting it. Compared thus, the UV Waterworks is 20,000 times more energy efficient than boiling water over a cookstove. We should also mention that the outlet water is ready for use instantly -- there is no need to wait for it to cool, nor for any odor to disappear.

9. What are the safety issues involved in using UV Waterworks?

UV light used in the UV Waterworks is intense, and is very harmful to all living organisms. So, the UV Waterworks does not have an operable lid. The cover is fitted onto the body with 14 screws. There are warning signs in local languages on the device not to open it without first disconnecting power. The safety viewing window of the device is made of 4 mm thick polycarbonate, and is opaque to UV light. The metal case of the device is grounded, and UL guidelines have been followed in the design of the device. We recommend that the device should be powered from a GFCI (ground fault circuit interruption) protected outlet if powered with a source voltage greater than 110 volts.

10. How much does it cost to use per person per year?

The cost goal of the design has been to afford protection for persons in a rural setting at a cost considered affordable by developing country standards. Officers in India's National Drinking Water Mission consider a cost of 20 ¢ per person per year

affordable. With UV Waterworks, it costs about 7 ¢ per person annually to disinfect his/her 10 liters of drinking water per day, about three times lower than the upper cost limit stated above. (This estimate assumes that UV Waterworks is used to supply disinfected drinking water for a community of 1000 persons.)

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